Moored Array Technology: Mooring Design Investigation for the Autonomous Ocean Sampling Network Experimental Program

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LONG-TERM GOAL

The long-term goal of the Moored Array Technology program is the development and at-sea testing of new mooring and telemetry techniques for use in oceanography. Areas of concentration include mooring and buoy designs, in-water telemetry techniques, and application of emerging satellite and networking technologies.

OBJECTIVES

The specific objective for 2000 was the design and fabrication of four coastal telemetry moorings to be used in conjunction with the Monterey Bay MUSE 2000 experiment to facilitate the collection of acoustic communications data, to collect real-time current profile data, and to provide communications support to AUVs operating in the study area. On the mooring component level, the objective was to verify that the high stretch rubber hose design was reliable. Two high-stretch hoses were tested and each survived over 100,000 load cycles.

APPROACH

The Autonomous Ocean Sampling Network (AOSN) concept [1] envisions the use of a variety of autonomous platforms to collect spatial and time series environmental data. These data need to be telemetered in near real time to the system users. One way to accomplish this telemetry is to moor surface buoys in the measurement area and use these buoys as platforms for radio frequency (RF) links to either satellites or local nodes. A difficulty with this approach has been the cost, complexity, and special-purpose nature of these moored buoy systems.

Our goal in 1999 and 2000 was to build an array of a very simple, low-cost coastal moorings that combined flexibility and ease of use with real-time telemetry links through the water and the atmosphere. Our approach was to use a small, rugged surface platform that contained an off-the-shelf RF modem (Free Wave Model DGR09AS). This modem was integrated directly with one of our WHOI-developed acoustic modems, the UAM or Utility Acoustic Modem [2]. The telemetry buoys receive and transmit acoustically as well as receive and transmit via RF. By concentrating on simplicity and ease of use, we were able to develop a coastal telemetry mooring with a cost of less than $10K, including all materials, electronics, RF and acoustic modems, batteries, light, mooring, anchor,

etc. Labor to assemble and test the system is one to two technician weeks. Two people from a small boat without any serious deck gear can install a typical mooring system (Figure 1).

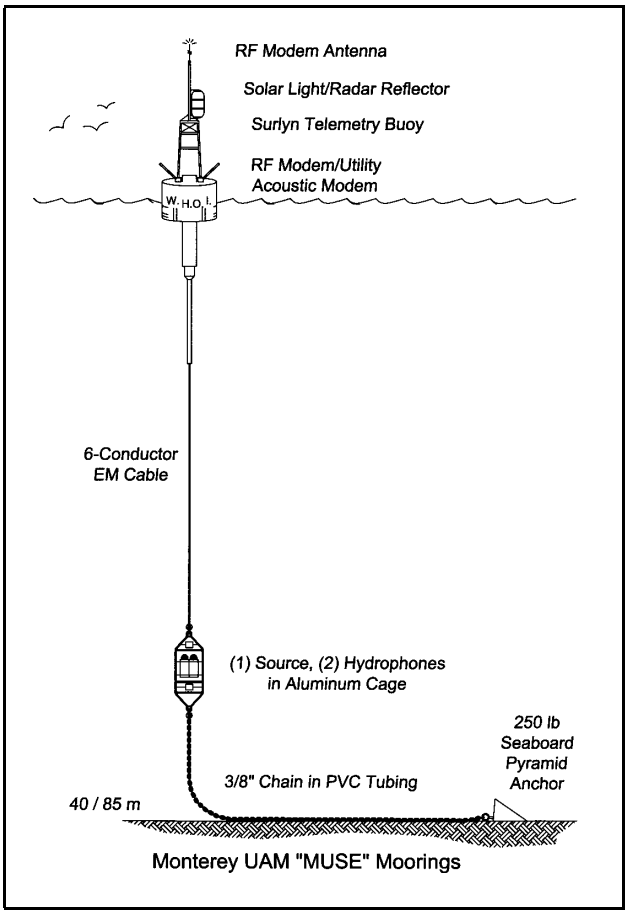

Figure 1. One of the low-cost telemetry moorings that was deployed in Monterey Bay in August 2000 in support of the MUSE 2000 field experiment.

WORK COMPLETED

Coastal Telemetry Buoy

The MURI-AOSN project (program #ONR-322 OM/AOSN N00014-95-1-1316) led by MIT (J. Bellingham, P.I.) conducted a field trial of AOSN vehicles and related technologies in Monterey Bay in August/September 2000 as part of the MUSE 2000 experiment. We built four coastal telemetry buoys for use on this effort. They were deployed in 40-85 m of water (Figure 2) during this experiment and were used to test acoustic communication systems installed on the Odyssey AUVs and to test communication algorithms that were transmitted and received from the *R/V Shana Rae* to the buoys. All four systems functioned reliably following installation and reliable acoustic links from ship to buoy, from buoy to buoy, and from shore to buoy were established. Several moorings suffered from a software problem in the RF modem electronics part of the way through the deployment that has yet to be resolved.

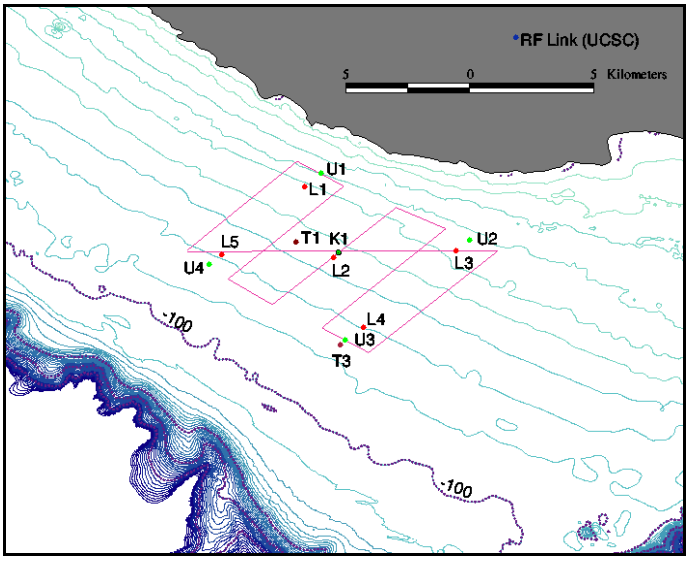

Figure 2. Locations of the four telemetry moorings (U1-U4) deployed just north of Monterey Bay. Contours are in meters. The NPS-ADCP was located near mooring U3.

The four moorings were deployed in a rectangular array offshore Santa Cruz in an area of strong currents and strong afternoon winds. A shore station located at the Long Marine Lab provided connection to scientists on shore for data collection and for command and control information to be forwarded to the AUV(s) offshore. A variety of rates were used for the acoustic communication tests using frequency-hopped FSK techniques designed for maximum reliability at moderate baud rates, spread spectrum techniques and phase coherent techniques.

At mooring U3 the Naval Post Graduate School (Steve Ramp) installed an ADCP in a trawl resistant frame. We interfaced an acoustic modem to the instrument and transmitted hourly current profiles, which the moorings then relayed to shore. These systems had enough range that even U1 (about 8.5 Km distant) was able to forward most of the data.

Conducting Nylon Rope

A new rope design for use with electrical conductors was developed. Axial contraction in the rope is prevented by enclosing the 12 by 12 strand braided rope with a thin, non-load bearing outer braid. A new termination is used to secure each of the 12 load carrying braided strands in a 'tuck and bury' eye splice without choking the electrical core.

High Stretch Mooring Hose

The purpose of this effort is the development of a rugged mooring element that can stretch over 100 percent. This element can be used in shallow water, open ocean surface buoy moorings. The selected design is a modification of the proven reinforced rubber hoses developed at WHOI. The new design applies the nylon reinforcement in a geometry, which will allow the rubber hose to stretch without any reinforcement restraint. Once a desired stretch level is exceeded, the reinforcement will engage, and begin to share a portion of the load. Two different designs were built as eight-foot long test samples – A medium stretch sample, which stretches about 50 percent and a high stretch sample with about 100

percent elongation. These hoses were subjected to cyclic extension tests between 300 and 1900 lbs. tension at Tension Member Technology (TMT). The medium stretch hose passed 115,000 cycles and the maximum stretch hose passed 127,000 cycles without failure. The test behavior is shown in Figure 3. The lower portion of the curves are distorted since they were taken without allowing time for the sample to relax after the previous load cycle (load cycle duration 4-5 seconds). Since rubber is visco-elastic in nature, testing and time between load cycles affects the load extension behavior.

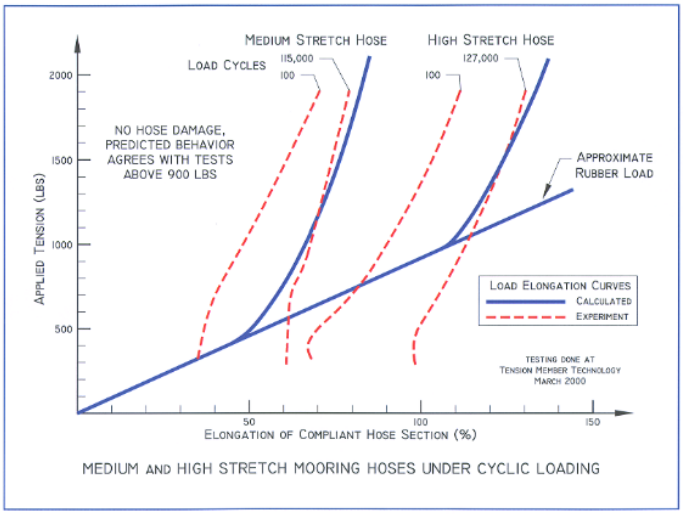

Figure 3. Results from High Stretch Hose Axial Fatigue Cycling Tests

The test results are considered significant because little is known about rubber behavior in cyclic tension tests. Rubber behavior is well understood in compression and shear modes.

Buoy Workshop

The *ONR/MTS Buoy Workshop 2000* was held in May 2000 in Woods Hole. This was the third of a new series of Buoy Workshops, the two previous gatherings were convened in San Diego in 1996 and 1998. This year's 2 ½ day Workshop drew over 100 participants, up 25 percent from 1998. Thirty-one presentations were given. Foreign speakers came from Canada, Great Britain, and Taiwan. This year's theme was: *Going for the Long Haul, Oceanographic Buoy Systems for Long-Term Deployments.* Tours of selected laboratories and facilities at WHOI formed part of the program. A Buoy Workshop Website was set up. Abstracts and presenters' audio-visual materials are being collected and will form part of the first electronic Buoy Workshop Record.

RESULTS

We have designed, built and used low-cost coastal telemetry moorings in Cape Cod Bay and Monterey Bay that provide two-way communication between AUVs and investigators on ship or ashore. They use an integrated RF and acoustic modem and a simple mooring design, which brings the total system cost to about $10K per site. Two people can deploy them from a small boat. A total of nine moorings have been deployed.

IMPACT/APPLICATIONS

Coastal Telemetry Moorings

As described above, four coastal telemetry moorings were built and deployed on the August 2000 AOSN field trials just north of Monterey Bay.

We are also using a similar design for the NOPP project titled, "Low-Cost Modular Telemetry for Coastal Time-Series Data," Grant # N00014-98-1-0816. We have recently been funded by NAVOCEANO to provide three of these coastal telemetry systems for use in the Gulf of Mexico as part of a large environmental monitoring program. They will be used to telemeter ADCP data from the bottom to users on shore.

TRANSITIONS

Coastal Telemetry Moorings have been transitioned to MURI-AOSN Grant # N00014-95-1-1316.

Coastal Telemetry Mooring designs have been transitioned to NOPP and DURIP Grant #'s N00014-98-1-0816 and N00014-98-1-0429, respectively. Coastal Telemetry Mooring designs are in the process of being transitioned to an operational NAVOCEANO project in the Gulf of Mexico.

RELATED PROJECTS

Multidisciplinary University Research Initiative: "Real-Time Oceanography with Autonomous Ocean Sampling Networks: A Center for Excellence."

Under a support contract received from the National Data Buoy Center, design specifications are being developed for stretch hoses. These hoses are part of a planned modernization of weather buoy systems to enable satellite data transmission from submerged, in-line or bottom-mounted sensors.

Electromechanical mooring designs developed under the Moored Array Technology program have been used as the basis for an NSF-funded feasibility study to look at the use of deep ocean buoys as ocean observatories.

Electromechanical cabling designs are being used to anchor a large net cage in the Gulf of Maine as part of the University of New Hampshire's Open Ocean Aquaculture Program.

Coastal telemetry buoy designs are being used in the project**,** "Acoustically linked communications buoys for Gulf Coast ADCP Measurements." This project is funded by NAVOCEANO.

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